SAHTU SETTLEMENT AREA
VEGETATION CLASSIFICATION PROJECT
PROGRESS REPORT - 1999

Northwest Territories Resources, Wildlife & Economic Development

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ABSTRACT

The objective of the Sahtu Vegetation Classification Project (SVCP) is to provide baseline quantitative and descriptive data on vegetation within the Sahtu Settlement Area (283,000 km^2) for use in land, forestry, and wildlife management, land and water permitting, and land use planning. This information was not previously available for the region. To date, the SVCP has been a 3-year project (1997-98 to 1999-2000) co-ordinated and funded by the Department of Resources, Wildlife and Economic Development (DRWED) Sahtu Region and Forest Management (Fort Smith, NWT), with additional support and funding from the Sahtu Renewable Resources Board (Tulita, NWT). Again in 1999, our primary focus was ground-truthing LANDSAT thematic mapper images based on the 39 classes of vegetation or other cover that occurs on the ground at selected sites in the field. Detailed evaluation of images ground-truthed in 1998 strongly indicated that an insufficient number had been collected to do a successful final supervised vegetation classification and subsequent accuracy assessment. The number of ground truthing sites was increased from approximately 150 to 200-300 per image in 1999. We flew 93.6 h in helicopter in 1999 and collected 1053 ground-truthing sites for 9 separate satellite images. The supervised vegetation classification that will be the end-product of this project will assist resource managers and planners with co-management boards, community organizations, and government in decision-making and planning within the Sahtu. We anticipate that the SVCP will be completed by March 2001.

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INTRODUCTION

The objective of the Sahtu Vegetation Classification Project (SVCP) is to provide baseline quantitative and descriptive data on vegetation across the ecologically diverse Sahtu Settlement Area (283,000 km^2) for use in land, forestry, and wildlife management, land and water permitting, and land use planning. This information was not previously available for the region. The establishment of three resource co-management boards under the terms of the Sahtu Dene and Metis Comprehensive Agreement (1993) – the Sahtu Renewable Resources Board, the Sahtu Land Use Planning Board, and the Sahtu Land and Water Board – heightened awareness of the need to fill this knowledge gap in order to ensure efficient and effective resource management.

To date, the SVCP has been a 3-year project (1997-98 to 1999-2000) coordinated and funded by the Department of Resources, Wildlife & Economic Development (DRWED) Sahtu Region and the Forest Management Division (FMD) in Fort Smith, Northwest Territories (NWT). Additional support and funding has been received from the Sahtu Renewable Resources Board (Tulita, NWT). In 1997, the project was designed in consultation with researchers involved in vegetation classification in other regions of the NWT at a workshop hosted by the FMD in Fort Smith. The 1999 field season was the second successful year of fieldwork for the SVCP. As outlined in detail in the 1998 summary report (Theisenhausen and Veitch 1998), the SVCP uses LANDSAT Thematic Mapper (TM) 7-band digital images (Figure 1) and extensive ground-truthing of those images to produce a detailed classification of the vegetation types that occur across the Sahtu. Thiesenhausen and Veitch (1998) provide additional information on LANDSAT TM imagery and general image classification procedures.

Ground-truthing involves identifying and selecting sites on the satellite images and then visiting those sites in either a fixed-wing aircraft or helicopter. At the site, we describe and record the vegetative cover on a standard data form (Figure 2), and take a set of representative colour print photographs (400 ASA; Appendix 1). Once collected, ground-truthing sites are used to 'train' specialized computer software (*ERMapper* 6.0, Earth Resources Mapping, San Diego, CA) to identify each cover class on the image. The computer can then do a 'supervised vegetation classification' where each 30 m x 30 m pixel on the image is put into one of the 39 ground cover

classes described in Appendix 1. A CD-ROM containing full-colour representative photographs of the cover classes is available. Refer to the end of Appendix 1 for information on how to order this CD-ROM.

Lillesand and Kiefer (1987) suggest that each cover class requires the collection of a minimum 10 pixels per band on each image for training the computer prior to a supervised vegetation classification. A LANDSAT TM image is composed of 7 wavelength bands, but one is not used in vegetation classification. Therefore, 6 training sites of at least 180 x 180 m are required per cover class for each TM image. In addition to the 6 training sites, an additional 3 ground-truthing sites are required for an assessment of accuracy after the supervised vegetation classification has been done. Therefore, we require 9 ground-truthing sites per cover class for each image.

Evaluation of images ground-truthed in 1998 (Veitch and Thiesenhausen 1998) strongly indicated that insufficient ground truthing sites had been collected. The SVCP uses 39 different vegetation and land cover classes (Appendix 1); however, as a result of vegetation diversity among images (e.g., alpine versus boreal forest) normally only 22 to 27 of the total classes are used per image. Therefore, each image requires between 200 and 300 ground-truthing sites.

Ground-truthing has been mostly completed for the following images (Figure 1): Colville, Fort Good Hope, Sheep/Keele River, Canol/Mile 222, Tulita, Grandview, Blackwater, Keller Lake, Hottah Lake, Smith Arm, and Wrigley/Drum Lake. The supervised classification on those images will be run prior to the 2000 field season. We may need up to 220 additional ground-truthing sites for those images so that the required accuracy assessment can be done. The Horton Lake, Dease Arm, Caribou Point, and Deline images were purchased in January 2000 (Figure 1) and ground-truthing on those images will also be done during the 2000 field season.

As in previous years, we collaborated closely with staff from the FMD in order to produce a single, comprehensive vegetation classification for the entire mainland of the NWT using similar field and office procedures and identical cover classes. In 1999, personnel with FMD flew ground-truthing flights in areas north, south, and east of the Sahtu (Bruno Croft, FMD, DRWED, Fort Smith, NWT, personal communication). Some of those images overlap the Sahtu

and thus are of direct benefit to the SVCP. In turn, we assisted the FMD with ground-truthing the Blackwater Lake image (Figure 1). The 93.6 h of helicopter time flown by the SVCP in 1999 was paid for by the FMD and we are grateful for the continued support for the SVCP by the FMD in both Fort Smith and Norman Wells.

Biologists with *Ducks Unlimited, Canada* (DUC) also flew additional ground-truthing sites for the Tulita image (Figure 1) in 1999, which added to those flown by the SVCP in 1998 (Thiesenhausen and Veitch 1998). Given DUC's specific interest in wetlands as waterfowl habitat, their objective was to expand the wetland classes used by the SVCP (Appendix 1) and to increase accuracy of wetland classification (Dave Kay, DUC, Yellowknife, NWT, personal communication). DUC located and purchased an older LANDSAT TM image than the one held by the SVCP (08/07/92; Figure 1). Therefore, this will allow detection of any changes in vegetation cover over time.

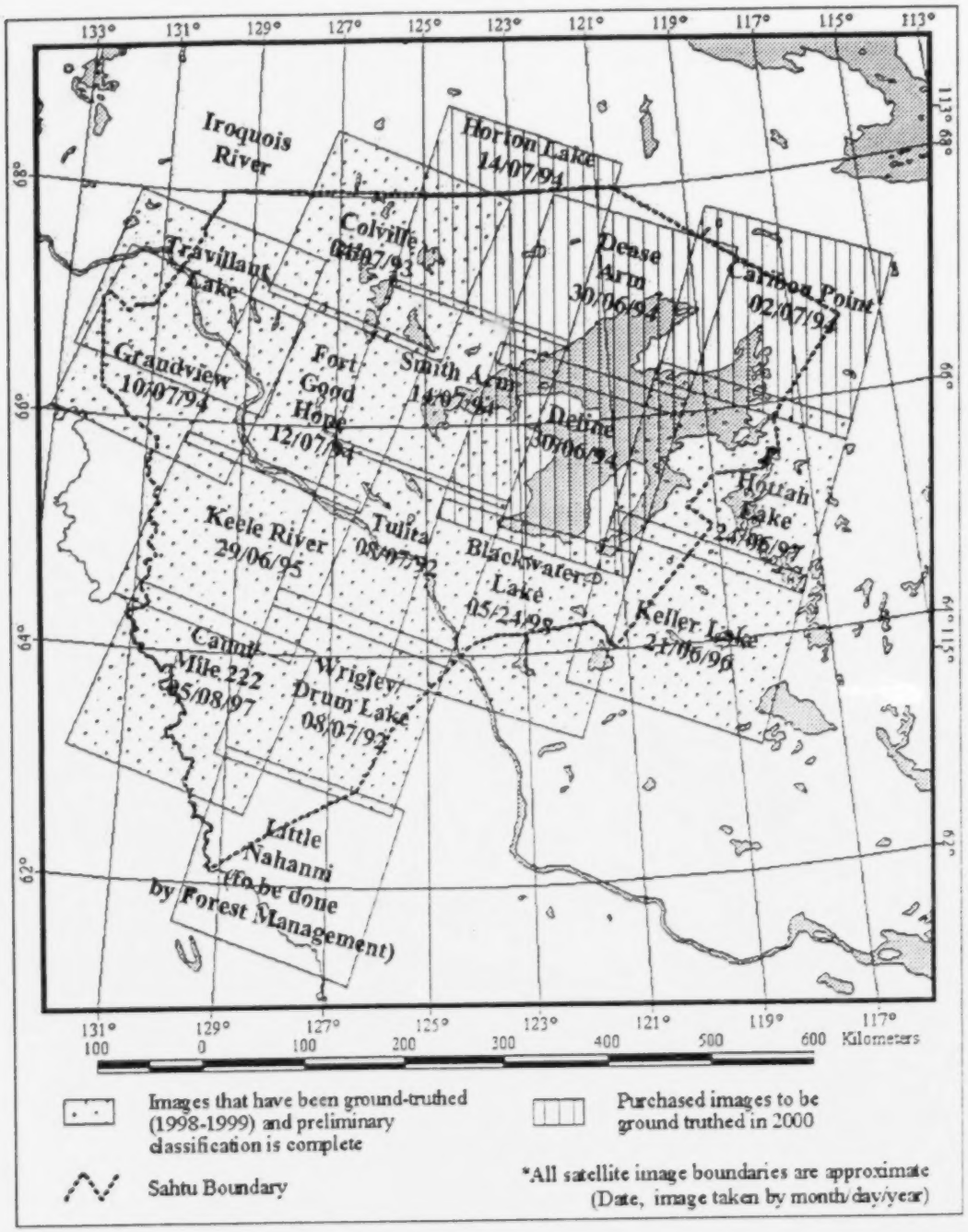

Figure 1. LANDSAT TM image coverage of the Sahtu Settlement Area.

METHODS AND RESULTS

Image Preparation

1. *Selection of appropriate images* – LANDSAT TM images were selected based on year (most recent suitable image after 1991), season (between 08 June and 30 August to ensure vegetation is in full leaf), and cloud cover (less than 10 %). Natural Resources Canada (Sherbrook, Quebec) maintain an Internet site (*ceocat.ccrs.nrcan.gc.ca*) that we used to browse available images based on the preceding criteria. The most suitable image was then purchased from *RADARSAT International* (Richmond, BC).

2. *Georeferencing the image* – using *ER Mapper*, we located specific geographic reference points on the image, e.g., the confluence of two rivers. These points were then located on the corresponding 1:250,000 scale National Topographic System (NTS) digital base map stored in the central database of the *Sahtu GIS Project* (Veitch and Leverington 1999). When a sufficient number of such reference points had been entered into *ER Mapper*, the image was georeferenced by the software. Georeferencing also allows the images to be combined with other data layers of the *Sahtu GIS Project* (Veitch and Leverington 1999).

3. *Printing the image* – two copies of each image were printed at 1:100,000 scale. Each image was cut into 8 approximately equal sections to make them more manageable, especially on board aircraft during ground-truthing flights. Each image section was then laminated in plastic to increase durability and provide protection from moisture.

4. *Ground-truthing site selection and update* - for each image, approximately 200-300 ground-truthing sites were visually selected based on uniformity in colour or pattern and the ease of locating the site in the field based on recognizable geographic features. Each ground-truthing site was circled on the image sections and given a unique identifying number. All sites were then copied onto the duplicate set of image sections, which allowed each technician to have a copy on board the aircraft.

5. *Verification of ground-truthing sites* - *ER Mapper* was used to determine the latitude and longitude of each ground-truthing site. Those coordinates were then pre-programmed

into the aircraft's global positioning system (GPS) prior to each flight. The coordinates and identification number of each ground-truthing site were entered onto a computer spreadsheet for printout, imported back into *ERMapper*, and overlaid as points on the TM image. Finally, 2 copies of the image showing all ground-truthing sites were printed at 1:500,000 scale for preparation of flight lines and for in-flight use (image overview).

Ground-truthing Flights

In 1999, additional ground-truthing sites were selected and ground-truthed on the Canol/Mile 222, Colville, Wrigley/Drum Lake, Sheep/Keele, and Fort Good Hope images (Table 1). We also purchased and began ground-truthing the Smith Arm and Grandview images.

The most efficient flight route was determined prior to a flight, taking into consideration the distribution of ground-truthing sites, fuel, and terrain. On average, 25-30 sites were completed between fuel stops for the helicopter. Once the sequence of ground-truthing sites was determined, the sites were selected from the database using their identifying numbers and a sequential list was printed. Three copies of this flight itinerary were printed - one was left with the Duty Officer at the DRWED office in Norman Wells, who had direct radio contact with the aircraft, and one for each technician in the aircraft. The sequential itinerary was also used to pre-programme the aircraft's GPS.

In 1999, we visited each selected ground-truthing site via helicopter; FMD personnel flew their sites in fixed-wing aircraft (Bruno Croft, personal communication). These flights required at least two Vegetation Classification Technicians to accompany the pilot. Technicians were responsible for programming the GPS, navigation to ground-truthing sites, taking photographs, and recording the ground cover at each site. Each technician was responsible for verifying that the data were complete and accurate, and that the site had been correctly located based on site orientation, surrounding features, and prior experience working with LANDSAT TM images.

Safety and preparedness of the crew was always the primary concern. In addition to the aircraft's on board survival and emergency equipment, a pack containing a comprehensive supply of survival equipment and food was carried during all ground-truthing flights. Each member of the flight crew had fully reviewed the contents of the pack and was familiar with their purpose. Each crew member (excluding the pilot) was also required to wear an approved aviation helmet with built-in headphones and microphone, fire retardant coveralls, and leather safety boots at all times while on board the helicopter.

Table 1. Summary of LANDSAT TM image ground-truthing sites collected within the Sahtu Settlement Area in 1998 and 1999.

TM Image	# Sites Collected (1998)	# Sites Collected (1999)	Total to Date	Estimated # to Complete
Tulita	174	19	193	28
Wrigley	152	94	246	18
Keele River	175	37	212	37
Canol	151	121	272	28
Colville	119	95	214	25
Fort Good Hope	139	111	250	42
Grandview	0	236	236	17
Smith Arm	0	300	300	27
Blackwater Lake	0	40	40	0
Hottah Lake	50	0	50	0
Keller Lake	100	0	100	0
TOTALS	1060	1053	2113	222

Table 2. Dates and hours flown for ground-truthing LANDSAT TM images within the Sahtu Settlement Area in 1999.

Date (dd/mm/yy)	Zimmer (hrs)	Trembath (hrs)	Whiteman (hrs)	Image Flown
06/05/1999	6.8	6.8		Smith Arm
06/06/1999	4.7	4.7		Fort Good Hope
06/30/1999	6.4	6.4		Wrigley/Drum Lake
07/01/1999	6.1	6.1		Wrigley/Drum Lake
07/03/1999	7.8	7.8		Smith Arm
07/04/1999	8.1	8.1		Smith Arm
07/06/1999	5.1		5.1	Smith Arm
07/08/1999	7.4		7.4	Grandview
07/12/1999	6.6	6.6		Grandview
07/13/1999	9.7	9.7		Grandview
07/19/1999	5.5		5.5	Blackwater Lake
07/20/1999	10.1	10.1	10.1	Colville
08/05/1999	9.3	9.3	9.3	Canol/Mile 222
Totals	93.6	75.6	37.4	

Data Preparation

1. *Organization of 1998 sites* - organization of ground-truthing sites collected in 1998 was required to verify that the required additional sites were collected in 1999. Ground-truthing sites were organized by detailed examination of corresponding photographs and by the satellite imagery data forms. All ground-truthing sites were then grouped based on cover class and each site was compared with sites in the same cover class on other images to ensure consistency. Where a ground-truthing site overlapped $\geq$2 images, the overlap was recorded on the data form. Ground-truthing site data forms were collated first by image and then by cover class.
2. *Organization of 1999 sites* – sites collected in 1999 were also organized, filed, and stored as described above. These sites were compared to those collected in 1998 to ensure consistency of cover classes.

3. *Copying site locations* - all ground-truthing sites from the new Grandview and Smith Arm images, and additional sites for images flown in 1998, were recorded on a set of duplicate laminated image sections. The sites were circled on both sets of image sections and on overlapping images with their identification numbers clearly marked beside them.
4. *Cover class descriptions* – an extensive literature review of other projects that involved vegetation classification from LANDSAT TM images was done at the end of the 1999 field season. These were used to fine-tune the descriptions of cover classes that occur in the Sahtu. All ground-truthing sites collected in 1998 and 1999 had to be further organized following this work to ensure our cover classes matched the new descriptions.
5. *Master data form* – geographically referenced information about all ground-truthing sites is stored electronically in a database file by identification number. This file is incorporated into the GIS to create a data layer that shows all ground-truthing sites collected and ground-truthed. This file includes the following columns (Figure 3):

   Site - the unique identification number of each ground-truth site. An identification number may occur more than once because of overlap with other images.
   Original – the image for which the ground-truthing site was first collected.
   Veg Type – the broad vegetation category (e.g., shrub, tree, bog, etc.) of the ground-truthing site. Also records those ground-truthing sites that were not flown or dropped because they could not be located, were deemed unsuitable (e.g., due to slope/aspect problems), or a sufficient number of ground-truthing sites had already been obtained for that cover class.
   Class Code – a word or abbreviation that describes the cover class that occurs at the ground-truth site (Appendix 1).
   TR/AS – indicates if the site is to be used as a ground-truthing site (TR) or as an accuracy assessment site (AS). Those sites that overlap the original image are indicated by TOV and accuracy assessment sites that overlap are indicated by AOV.
   UnCl Colour – unclassified colour of the ground-truth site on the printed image section(s).
   Map – each laminated image section was given a number from 1 to 8; some sections were further divided and were identified as A and B.
   LAT – the latitude (N) of the ground-truth site in degrees, minutes, and seconds.
   LONG – the longitude of the ground-truth site (W) in degrees, minutes, and seconds.
6. *TM image summary forms* – information about each image (e.g., date image taken, the number of training sites collected per cover class, the number of accuracy sites, etc.) is recorded on this form (Figure 4). We also record the number of ground-truthing sites needed to obtain the required 200 to 300 per image.

SATELLITE IMAGERY DATA SHEET

GENERAL INFORMATION :

Transect No. : _____
Site No. : _____
Coordinates : _____E_____N
Image Map Sheet : _____
Colour of site on satellite image : _____

Observer : _____
Date : _____
Source : ☐ Fixed Wing ☐ Helicopter ☐ Ground ☐ Air photos
ID:____ Scale:____

TOPOGRAPHIC AND SITE DESCRIPTION :

Location : ☐ Ridge top ☐ Upper slope ☐ Mid slope ☐ Lower slope ☐ Upland bench ☐ Alluvial flat ☐ Other : _____

Slope : ☐ 0-30% ☐ 31-40 ☐ 41-50% ☐ 51% and +

Aspect : ☐ North ☐ South ☐ East ☐ West

Site photos :
Roll-frame Look direction Time
_____
_____
_____
_____

VEGETATED AREAS (> 10 % VEGETATION) :

Forests : >10 % c.c. tree species

☐ Coniferous (= 75 %)
☐ Pine _____%
☐ Sb _____%
☐ Sw_____%
☐ Other_____%

☐ Deciduous (= 75 %)
Species : _____

☐ Mixed wood (No species > 75 %)
Species : _____

☐ Mature ☐ Young

☐ Closed (>40 % c.c.) ☐ Open (10- 40 % c.c.)

☐ Stunted

Ground cover :
☐ Lichen ☐ Lichen/Shrub ☐ Lichen/Moss ☐ Moss ☐ Moss/Shrub ☐ Sphagnum ☐ Water
☐ Burn ☐ Burn/Lichen ☐ Burn/Moss ☐ Sand ☐ Till/Gravel ☐ Rock ☐ Other :_____

Shrubs : > 25 % tree < 10 %

☐ Tall = 1,5 m in height
☐ Low < 1,5 m in height

☐ Closed (> 40 % c.c.)
☐ Open (25-40 % c.c.)

Ground cover :
☐ Lichen ☐ Lichen/Shrub ☐ Lichen/Moss ☐ Moss ☐ Moss/Shrub ☐ Sphagnum ☐ Water
☐ Burn ☐ Burn/Lichen ☐ Burn/Moss ☐ Sand ☐ Till/Gravel ☐ Rock ☐ Other :_____

Herbaceons : tree < 10 % shrubs < 25

☐ = 50 % herbs (fireweed, dogwood, lupine, lily, vetch, ...)
☐ = 50 % grasses, sedges, or other graminoids
☐ = 50 % sphagnum moss
☐ = 50 % lichen (not on bedrock)

Ground cover (if applicable) :
☐ Lichen ☐ Lichen/Shrub ☐ Lichen/Moss ☐ Moss ☐ Moss/Shrub ☐ Sphagnum ☐ Water
☐ Burn ☐ Burn/Lichen ☐ Burn/Moss ☐ Sand ☐ Till/Gravel ☐ Rock ☐ Other :_____

UNVEGETATED AREAS > 10% VEGETATION

Little or no vegetation : ☐ Recent burn to mineral soil ☐ Barren (rock, mudflats, developed areas, ...) ☐ Ice or snow

Water and wetlands : ☐ Wetlands
☐ < 25 % vegetation
☐ = 25 % vegetation
☐ Water > 2m (deep)
☐ Water = 2m (shallow)
☐ Floating or emergent vegetation
☐ Water clear
☐ Water cloudy, milky, opaque

Comments : _____
_____
_____

Figure 2. Ground-truthing data form used by the Sahtu Vegetation Classification Project.

Site	Original	Veg Type	Class Codes	TR/ AS	UnCl Colour	Map	LAT	LONG
1	Tulita	Shrubs	Sltr	AS	Red	1	654946	1270250
1	Good Hope	Shrubs	Sltr	AOV	Red	8A	654946	1270250
2	Good Hope	Shrubs	Sltr	AOV	red/orange	8B	652834	1265637
2	Tulita	Shrubs	Sltr	AS	red/orange	1	652834	1265637
3	Sheep	Shrubs	Slc	TOV	peach	6A	651554	1264321
3	Tulita	Shrubs	Slc	TR	peach	1	651554	1264321
4	Sheep	Abiotic features	Rock	AOV	dark pink	6A	651350	1263903
4	Tulita	Abiotic features	Rock	AS	light pink	1	651350	1263903
5	Tulita	Trees	Wscm	TR	olive	1	651407	1264150
5	Sheep	Trees	Wscm	TOV	olive	6A	651407	1264150
6	Tulita	Trees	Undiffcm	TR	green	1	651254	1263841
6	Sheep	Trees	Undiffcm	TOV	green	6A	651254	1263841
7	Sheep	Shrubs	Stc	TOV	yellow	6A	651428	1270646
7	Tulita	Shrubs	Stc	TR	yellow	1	651428	1270646
8	Tulita	Bog	Bog	AS	orange	1	651533	1271459
8	Sheep	Bog	Bog	AOV	orange	8A	651533	1271459
9	Tulita	Trees	Deccl	TR	bright green	1	651345	1272439
9	Sheep	Trees	Deccl	TOV	bright green	6A	651345	1272439
10	Tulita	Trees	Bscm	TR	olive	1	651232	1264841
10	Sheep	Trees	Bscm	TOV	olive	6A	651232	1264841
11	Good Hope	Trees	Bsomix	TOV	orange &green	8A	653924	1264516
11	Tulita	Trees	Bsomix	TR	light orange	2A	653924	1264516
12	Tulita	DROPPED						
13	Good Hope	Shrubs	Sltr	TOV	red	8B	653535	1263423
13	Tulita	Shrubs	Sltr	TR	red	2A	653535	1263423
14	Tulita	Trees	Bscm	TR	olive	2A	654056	1263820
14	Good Hope	Trees	Bscm	TOV	dark green	8A	654056	1263820
15	Tulita	LOST					654307	1260745
16	Tulita	Trees	Bsomix	AS	green	2A	653120	1262624
16	Good Hope	Trees	Bsomix	AOV	green	8B	653120	1262624
17	Good Hope	Trees	Mixcl	TOV	dark green	8B	653001	1262007
17	Tulita	Trees	Mixcl	TR	bright green	2A	653001	1262007
18	Tulita	Trees	Bsomix	TR	grey/cream	6B	652539	1261530

Figure 3. Example of the master data form used to store and organize information about ground-truthing sites by the Sahtu Vegetation Classification Project.

Site	Original	Veg Type	Class Codes	TR/ AS	UnCl Colour	Map	LAT	LONG
1	Tulita	Shrubs	Sltr	AS	Red	1	654946	1270250
1	Good Hope	Shrubs	Sltr	AOV	Red	8A	654946	1270250
2	Good Hope	Shrubs	Sltr	AOV	red/orange	8B	652834	1265637
2	Tulita	Shrubs	Sltr	AS	red/orange	1	652834	1265637
3	Sheep	Shrubs	Slc	TOV	peach	6A	651554	1264321
3	Tulita	Shrubs	Slc	TR	peach	1	651554	1264321
4	Sheep	Abiotic features	Rock	AOV	dark pink	6A	651350	1263903
4	Tulita	Abiotic features	Rock	AS	light pink	1	651350	1263903
5	Tulita	Trees	Wscm	TR	olive	1	651407	1264150
5	Sheep	Trees	Wscm	TOV	olive	6A	651407	1264150
6	Tulita	Trees	Undiffcm	TR	green	1	651254	1263841
6	Sheep	Trees	Undiffcm	TOV	green	6A	651254	1263841
7	Sheep	Shrubs	Stc	TOV	yellow	6A	651428	1270646
7	Tulita	Shrubs	Stc	TR	yellow	1	651428	1270646
8	Tulita	Bog	Bog	AS	orange	1	651533	1271459
8	Sheep	Bog	Bog	AOV	orange	8A	651533	1271459
9	Tulita	Trees	Decel	TR	bright green	1	651345	1272439
9	Sheep	Trees	Decel	TOV	bright green	6A	651345	1272439
10	Tulita	Trees	Bscm	TR	olive	1	651232	1264841
10	Sheep	Trees	Bscm	TOV	olive	6A	651232	1264841
11	Good Hope	Trees	Bsomix	TOV	orange &green	8A	653924	1264516
11	Tulita	Trees	Bsomix	TR	light orange	2A	653924	1264516
12	Tulita	DROPPED						
13	Good Hope	Shrubs	Sltr	TOV	red	8B	653535	1263423
13	Tulita	Shrubs	Sltr	TR	red	2A	653535	1263423
14	Tulita	Trees	Bscm	TR	olive	2A	654056	1263820
14	Good Hope	Trees	Bscm	TOV	dark green	8A	654056	1263820
15	Tulita	LOST					654307	1260745
16	Tulita	Trees	Bsomix	AS	green	2A	653120	1262624
16	Good Hope	Trees	Bsomix	AOV	green	8B	653120	1262624
17	Good Hope	Trees	Mixcl	TOV	dark green	8B	653001	1262007
17	Tulita	Trees	Mixcl	TR	bright green	2A	653001	1262007
18	Tulita	Trees	Bsomix	TR	grey cream	6B	652539	1261530

Figure 3 Example of the master data form used to store and organize information about ground-truthing sites by the Sahtu Vegetation Classification Project.

TM Image: Sheep ■

Vegetation Types	Class Codes	Training Sites				Accuracy Sites				Total Training and Accuracy Sites	Required Training and Accuracy Sites
		Image Sites	Overlap Sites	Image of Overlap Sites	Total Sites	Image Sites	Overlap Sites	Image of Overlap sites	Total Sites		
Trees	bsalm	5			5	2	1	Tulita	3	8	1
	bsogram	9			9	4	1	Wrigley	5	14	0
	bsollen	3			3	1	1	Grandview	2	5	4
	bsomix	6	3	Wr(3)	9		4	Gr(2); Wr(2)	4	13	0
	bsoshrub	N/F			0				0	0	7
	wsalb	7			7	2	2	Ca(1); Tu(1)	4	11	0
	wsosamd	N/F			0				0	0	
	wsoshrub	4			4	1	1	Wrigley	2	6	3
	wsoslol		2	Wrigley	2		1	Wrigley	1	3	6
	undiffcm	2	2	Tu(1); Wr(1)	4	1	1	Wrigley	2	6	2
	undiffcm		2	Wrigley	2		1	Wrigley	1	3	6
	undiffy	N/F			0				0	0	
	decid	4	3	Tu(1); Wr(2)	7	2	2	Ca(1); Tu(1)	4	11	0
	mixed	6	1	Wrigley	7	1	2	Gr(1); Wr(1)	3	10	0
Shrubs	slc		1	Tulita	1				0	1	8
	sld	4	3	Ca(1); Wr(2)	7	3	1	Wrigley	4	11	0
	slo	2	1	Wrigley	3		1	Tulita	1	4	3
	slol	3			3	2			2	5	4
	slt	7			7		3	Tu(1); Wr(2)	3	10	0
	stc	2	1	Tulita	3		2	Tu(1); Wr(1)	2	5	4
Herbaceous	drysedge	N/F			0				0	0	
	er	9			9	1	4	Tu(2); Wr(2)	5	14	0
	lich	3	1	Wrigley	4	1	1	Wrigley	2	6	3
	sdjelich	7			7		3	Wrigley	3	10	0
	shbsedge	10	1	Tulita	11	3	2	Wrigley	5	16	0
Bog	bog	1	1	Tulita	2				0	2	7
	hcmdp		1	Tulita	1				0	1	8
	ptp		1	Tulita	1				0	1	8
Aquatic	lbog	2			2				0	2	7
	patfen	N/F			0				0	0	9
	pondfen	1			1				0	1	8
	shorefen		3	Wrigley	3				0	3	6
Abiotic features	cloud				0				0	0	0
	ice	2			2	1			1	3	0
	rock	6	3	Ca(1); Tu(2)	9	2	3	Ca(1); FCH(1); Tu(1)	5	14	0
	shadow				0				0	0	0
	water				0				0	0	0
	watersed	1			1				0	1	0

Figure 4. Example of the TM image summary form used to store and organize data on the number of ground-truthing sites collected for each cover class used by the Sahtu Vegetation Classification Project.

TM Image: Sheep ■

Vegetation Types	Class Codes	Training Sites				Accuracy Sites				Total Training and Accuracy Sites	Required Training and Accuracy Sites
		Image Sites	Overlap Sites	Image of Overlap Sites	Total Sites	Image Sites	Overlap Sites	Image of Overlap sites	Total Sites		
Trees	bscn	5			5	2	1	Tulita	3	8	1
	bsgram	9			9	4	1	Wrigley	5	14	0
	bsolicn	3			3	1	1	Grandview	2	5	4
	bsomix	6	3	Wr(3)	9		4	Gr(2); Wr(2)	4	13	0
	bsoshrub	N/F			0				0	0	7
	wscn	7			7	2	2	Ca(1); Tu(1)	4	11	0
	wsosand	N/F			0				0	0	
	wsoshrub	4			4	1	1	Wrigley	2	6	3
	wsoslol		2	Wrigley	2		1	Wrigley	1	3	6
	undiffcn	2	2	Tu(1); Wr(1)	4	1	1	Wrigley	2	6	2
	undifmm		2	Wrigley	2		1	Wrigley	1	3	6
	undifly	N/F			0				0	0	
	decd	4	3	Tu(1); Wr(2)	7	2	2	Ca(1); Tu(1)	4	11	0
	mixd	6	1	Wrigley	7	1	2	Gr(1); Wr(1)	3	10	0
Shrubs	slc		1	Tulita	1				0	1	6
	slcl	4	3	Ca(1); Wr(2)	7	3	1	Wrigley	4	11	0
	slo	2	1	Wrigley	3		1	Tulita	1	4	3
	slol	3			3	2			2	5	4
	sltr	7			7		3	Tu(1); Wr(2)	3	10	0
	stc	2	1	Tulita	3		2	Tu(1); Wr(1)	2	5	4
Herbaceous	drysedge	N/F			0				0	0	
	er	9			9	1	4	Tu(2); Wr(2)	5	14	0
	lich	3	1	Wrigley	4	1	1	Wrigley	2	6	3
	sdgelich	7			7		3	Wrigley	3	10	0
	shrbsdge	10	1	Tulita	11	3	2	Wrigley	5	16	0
Bog	bog	1	1	Tulita	2				0	2	7
	bcngdp		1	Tulita	1				0	1	8
	ptp		1	Tulita	1				0	1	8
Aquatic	fiveg	2			2				0	2	7
	pattern	N/F			0				0	0	9
	pondfen	1			1				0	1	6
	shorefen		3	Wrigley	3				0	3	6
Abiotic features	cloud				0				0	0	0
	ice	2			2	1			1	3	0
	rock	8	3	Ca(1); Tu(2)	9	2	3	Ca(1); FGH(1); Tu(1)	5	14	0
	shadow				0				0	0	0
	water				0				0	0	0
	watersed	1			1				0	1	0

Figure 4. Example of the TM image summary form used to store and organize data on the number of ground-truthing sites collected for each cover class used by the Sahtu Vegetation Classification Project.

CONCLUSION

The SVCP has completed two successful years of collecting detailed descriptive and quantified data on the vegetation cover across the Sahtu Settlement Area. We anticipate that the SVCP will be completed by March 2001. The supervised vegetation classification that will be the end-product of this project will assist resource managers and planners with co-management boards, community organizations, and government in decision-making and planning within the Sahtu. However, it is also important to remember that the vegetation classification will, over time, change as a result of forest fire, normal plant succession processes, human use, etc. The vegetation and abiotic classes currently listed may change after the supervised vegetation classification has been run, since some similar classes may need to be combined to increase overall accuracy. The classification scheme cannot be finalised until both preliminary accuracy checks and the final accuracy assessment have been completed. Also, few ground-truthing sites have been flown in those images that primarily cover barren-ground tundra; therefore, additional cover classes may be required.

ACKNOWLEDGEMENTS

We would like to extend our deep appreciation to the following people and organizations for making the SVCP possible in 1999:

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2) DRWED staff with the Sahtu Region, Norman Wells, NWT assisted in all facets of the SVCP again in 1999. We are especially grateful for the long hours that Tanya Townsend and Lisa Duncan put in monitoring the radio, especially on weekends. Paul Rivard (Manager, Forests) secured access to Forest Management's fire contract helicopter for the SVCP.

3) The Sahtu Renewable Resources Board, Tulita, NWT again provided financial support to hire one SVCP technician and for purchasing a digital LANDSAT TM image.

4) *Ducks Unlimited Canada*, Yellowknife, NWT flew additional ground-truthing sites on the Tulita image and shared their results with the SVCP.

5) Jim Broadbent, pilot, *Great Slave Helicopters Ltd.*, Norman Wells, NWT safely flew the crew for all helicopter ground-truthing flights.

6) *Yellowknife Foto Source* (Yellowknife, NWT) provided prompt and reliable photofinishing service throughout the field season.

7) Lynda Yonge, DRWED, Yellowknife, NWT co-ordinated the final preparation and publication of this Manuscript Report.

REFERENCES

Lillesand, T. and R. Kiefer. 1987. Remote sensing and image interpretation. John Wiley & Sons, Toronto, ON. 680 pp.

Thiesenhausen, K. and A. Veitch. 1998. Vegetation classification project, Sahtu Settlement Area -summary of the 1998 field season. Manuscript Report No. 112, Dept. of Resources, Wildlife & Economic Development, Norman Wells, NT. 17 pp.

Veitch, A. and L. Leverington. 1999. Sahtu Settlement Area GIS Project, July 1996 – July 1998. Manuscript Report No. 111, Dept. of Resources, Wildlife & Economic Development, Norman Wells, NT. 20 pp.

Appendix 1. Vegetation and ground cover classes used in the Sahtu Vegetation Classification Project.

Black Spruce-dominated

Closed, Mature Black Spruce (BSCM) - occurs on wet sites in both the Mackenzie Mountains and Mackenzie River valley.
- Usually tall and healthy-looking, not stunted
- Branches with needles still attached down most the length of the trunk
- Groundcover difficult to distinguish due to density of canopy cover
- Sphagnum moss and shrub are most common groundcover

Open Black Spruce with Graminoid Understory (BSOGRAM) - occurs in the Mackenzie Mountains in moist sites
- Black spruce trees are stunted and largely unhealthy; have a typical 'blob' at the crown
- Includes hummocky terrain with a peat base
- Found on alluvial active and ancient flood plains with little or no peat deposits
- Grasses and sedges dominate the groundcover

Open Black Spruce on Lichen-dominated Peat Plateau (BSOLICN) - occurs on wet sites in the Mackenzie Mountains and Mackenzie River valley
- Black spruce trees with a fuller appearance; often associated with tamarack
- Low shrub is a commonly found in association with this class
- Generally has <10% sphagnum moss
- This class not well represented in ground-truthing; only a few sites were collected

Open Black Spruce on Sphagnum-dominated Peat Plateau (BSOMOSS) - occurs only in the Mackenzie River valley on wet sites
- Black spruce trees are generally stunted, but seldom associated with tamarack
- Very few ground-truth sites collected
- Undercover dominated by sphagnum moss; generally <10% lichen
- Shrubs also occur in association with this class

Open Black Spruce with Shrub-dominated Understory (BSOSHRUB) - found in the Mackenzie Mountains and Mackenzie River valley on very dry sites
- Healthier black spruce trees; no associated tamarack
- Does not occur on peat plateaus, but does occur in association with lichen-covered earth
- Moss not commonly associated with this class

Open Black Spruce on Mixed Understory (BSOMIX) - occurs on wetter sites in the Mackenzie Mountains and Mackenzie River valley; well represented class
- Black spruce trees in variable states of health
- Occurs on peat plateaus without a dominant groundcover; mixtures of moss, lichen, and shrub

White Spruce-dominated

Closed, Mature White Spruce (WSCM) - occurs on well drained sites near rivers or on slopes in the Mackenzie Mountains and Mackenzie River valley
- Very healthy, densely-growing stands of white spruce trees
- Groundcover hard to determine due to dense crown cover
- Variable groundcover - most often sphagnum moss and shrub. Lichen cover highly variable

Open White Spruce on Lichen and Sand (WSOSAND) - occurs north of the Arctic Circle only in the Mackenzie River valley on well-drained sand
- Healthy white spruce trees growing individually
- Groundcover of mixed lichen and low, open shrubs growing on sandy substrate

Open White Spruce with Shrub-dominated Understory (WSOSHRUB) – occurs on slopes and Mackenzie River valleys in the Mackenzie Mountains
- Healthy, well-spaced white spruce trees
- Low, densely-growing shrubs dominate understory mixed with lichen on well-drained sites;
- graminoids occur on some sites

Open White Spruce with Low Shrub and Lichen Understory (WSOSLOL) - occurs on well drained slopes and Mackenzie River valleys in the Mackenzie Mountains
- Healthy, well-spaced white spruce trees
-Low, sparse, and dense shrub layer on thick lichen groundcover

Undifferentiated Spruce-dominated

Closed, Mature Undifferentiated Spruce (UNDIFFCM) – occurs across the Mackenzie Mountains and throughout the Mackenzie River valley
- Spruce species undetermined for closed, mature stands
- High percentage of sphagnum moss and shrub groundcover for most sites and groundcover mostly obscured by dense crown cover

Open, Mature Undifferentiated Spruce (UNDIFFOM) - occurs in the Mackenzie Mountains and Mackenzie River valley on variable soil types
- Spruce species undetermined for open, mature stands
- Non-specific groundcover; however, tendency toward lichens and shrub

Open and Closed Young Undifferentiated Spruce (UNDIFFY) - occurs on well-drained sites throughout the Sahtu Settlement Area
- Young, healthy stands of trees variable in height (~1-3 m) and density of crown cover
- Ground cover mainly dense shrubs, with variable amounts of moss or lichen, or both
- Some sites difficult to differentiate from tall and low, closed shrub classes

Deciduous-dominated

Closed Deciduous Forest (DECCL) - occurs in the Mackenzie Mountains and Mackenzie River valley on well-drained or wet sites near rivers and streams
- Very dense canopy closure of deciduous species including aspen, birch, and poplar
- Groundcover of bare earth, leaf litter, rocks, moss, or shrub; rarely lichen groundcover

Open Deciduous Forest (DECOP) -
- Only 7 ground-truthing sites consisted of this class; therefore, it will not be included in the supervised vegetation classification (not in figure 2)

Mixed Coniferous and Deciduous-dominated

Closed Mixed Forest (MIXCL) - occurs on wet sites near rivers and streams; also occurs in drier, well-drained areas in association with white spruce
- Between 25-75% deciduous species
- Closed canopy overstory reduces visibility of groundcover
- Lichen rarely observed
- Visible groundcover primarily rock or bare earth, sphagnum moss, or bushes

Open Mixed Forest (MIXOP) -
- Only 6 ground-truthing sites consisted of this class; therefore, it will not be included in the supervised vegetation classification

Shrub-dominated

Low, Closed Shrub (SLC) - occurs in disturbed areas, such as old burns, ice flow clearing, seismic cutlines, and eroded areas
- Also occurs in alpine meadows and arctic tundra on well-drained areas with relatively high water availability
- Very dense, low shrubs - primarily dwarf birch and willow
- Some sites have associated tree cover of >10%
- Dense shrub layer generally obscures groundcover

Low, Open Shrub (SLO) - occurs in dry areas with less moisture and at higher elevations in well-drained regions of the Mackenzie River valley
- Most characteristic of alpine meadows
- Groundcover of lichen, grasses, and exposed earth or rock; shrubs are primarily dwarf birch and willow

Low, Closed Shrub with Lichen-dominated Understory (SLCL) - occurs in well-drained alpine areas and more northerly regions of the Sahtu
- >50% of groundcover is dense shrub, including dwarf birch and willow
- Remaining groundcover dominated by lichen-covered soil (not peat)

Low, Open Shrub with Lichen-dominated Understory (SLOL) - occurs in well-drained alpine areas and more northerly regions of the Sahtu
- <50% of groundcover is shrub
- remaining ground-cover is lichen-covered soil

Tall, Closed Shrub (STC) - occurs in the Mackenzie Mountains and Mackenzie River valley in both wet and dry areas, along waterways, and on mountain slopes
- Dense growth of shrubs, such as willow and dwarf birch, obscure visible groundcover
- Groundcover of mosses, lichens, or bare ground

Tall, Open Shrub (STO):
- No ground-truth sites consisted of this cover class; therefore, it will not be included in the supervised vegetation classification.

Low Shrub on Past Burn (SLTR) - occurs throughout the Sahtu, but is better represented in the Mackenzie River valley due to the greater amount of fuel available for forest fires
- Characterized by dead standing or fallen trees and exposed earth
- Young open or closed deciduous and coniferous shrubs/trees are dominant
- Groundcover primarily graminoids and other short-lived plant species on moist sites

Alpine and Arctic Meadows-dominated

Alpine/Arctic Lichen Meadow (LICN) - occurs in the Mackenzie Mountains on dry mounds and slopes
- Vegetation includes dwarf shrubs and graminoids
- Characterized by the open, exposed lichen not associated with peat deposits

Alpine/ Arctic Sedge and Lichen Meadow (SDGELICN) - occurs in the Mackenzie Mountains in dry, gently sloping areas
- Vegetation dominated by sedges and lichens
- Characterized by hummocks or tussocks where perennial sedge species form mounds

Alpine/ Arctic Dwarf Shrub and Sedge Meadow (SHRBSDGE) - occurs in the Mackenzie Mountains and north of treeline in more stable, gently sloping areas that feature less movement of rock and have an ample water supply
- Dwarf shrubs (primarily willow and birch) and sedges dominate

Alpine/ Arctic Dry Sedge Meadow (DRYSEDGE) - occurs along the Yukon border in dry, flat, and sloping regions
- Meadows of non-tussock sedges; low occurrence of dwarf shrub species

Alpine/ Arctic Meadow with Exposed Rock (ER) - occurs throughout the Mackenzie Mountains in steep, vegetated rock outcroppings
- Vegetation includes dwarf shrubs and sedges; mosses and lichens dominate moist sites
- Bare rock comprises 25% to 90% of groundcover

Bog

Peat Plateau (PTP) - occurs sporadically throughout the Mackenzie River valley
- Has sparse lichen cover on frozen, sphagnum-derived peat deposits, raised 1-2 m above the surrounding terrain
- Dwarf shrubs and other plant species rarely occur on this unstable, crack-prone peat substrate

Pocked Peat Plateau/ Open Sphagnum Bog (BOG) - occurs throughout the Mackenzie River valley
- Areas of sphagnum-covered pools of water surrounded by elevated, drier lichen and shrub areas
- ≤20% stunted black spruce trees occur in some ground-truth sites; however, the vegetation cover of those sites are sufficiently unique and identifiable that they cannot be classed in any of the open black spruce classes

Lichen-dominated Peat Plateau (LICNPTP) - occurs throughout the Mackenzie River valley with lichen-dominated peat plateaus
- Many ground-truth training sites in this class feature peat polygons formed by cracking of peat after freezing
- Dwarf shrubs, moss, and similar low-lying plant species occur with exposed and generally decomposing sphagnum moss

Fen

Patterned Fen (PATFEN) - occurs in the Mackenzie Mountains and Mackenzie River valley
- Characteristic patterned ridges and hollows formed from nutrient-rich, run-off water
-Varying graminoid cover in dry and waterlogged ponds encircled by shrub, tamarack, and spruce-covered ridges

Pond Fen (PONDFEN) - occurs almost exclusively in the Mackenzie valley along shallow water surfaces
-Represents one stage of lake in-filling in peat dominated regions
-Moss and sedges are the dominant vegetation types

Shore Fen (SHOREFEN) - occurs along streams and lake shores throughout the Sahtu
- Terrestrial and aquatic vegetation species advance from shore into open water where floating mats occur
- Sedges are the dominant vegetation type

Floating Vegetation (FLVEG) - occurs in primarily deep, cold, and clear lakes throughout the Mackenzie River valley
- ≥ 25% coverage of lily and other floating aquatic macrophytes

Abiotic

Ice and Snow (ICE) - occurs sporadically across the Mackenzie Mountains (including active glaciers) and regions of the Mackenzie River valley where pockets of snow and ice may remain through most or all summer months

Barren Rock, Sand, or Silt (ROCK) - occurs throughout the Sahtu Settlement Area, especially the Mackenzie Mountains
- ≥ 90% bare rock with little vegetation

Shallow/ Cloudy Water (WATERSED) - occurs throughout the Sahtu Settlement Area
- Characterized by cloudy, flowing water (e.g., muddy run-off), or light-coloured sediment in shallow lakes and ponds (generally < 2 m deep)

Note: you can obtain a copy of a CD-ROM that has representative full-colour photographs of each of these classes by contacting:

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Norman Wells, NT
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Ph: 867-587-2740
Fx: 867-587-2359
email: Lana_Robinson@gov.nt.ca

Appendix 2. A glossary of terms commonly used in vegetation classification and remote sensing.

abiotic class – a cover class that is not vegetated, such as bare rock or water.

accuracy site – a ground-truthing site that is used after the supervised vegetation classification to estimate the degree of accuracy of the classification.

accuracy site overlap – an accuracy site that occurs on ≥ 2 images due to overlap of adjacent images.

classified colour – the unique colour that is allotted to a cover class after the supervised classification of the image.

cover class- generalized grouping of vegetation based on dominant species (e.g., black spruce, shrubs) and their density (open versus closed).

digital image – the electronic version of the 7-band LANDSAT TM image, which can be stored and manipulated by computer using specialized hardware and software.

georeferencing – referencing the image so that it is geographically correct by latitude and longitude. Georeferencinig allows an image to be combined with other images and data layers.

GIS – geographic information system. It is computer hardware and software that can overlay multiple layers of digital geographically-referenced data (e.g., digital elevation models, recent forest fires, etc.).

ground-truthing – involves choosing sites on the satellite image based on uniformity in colour or pattern (e.g., patterned fen) and the ease of locating the site in the field based on recognizable geographic features. Those sites selected for ground-truthing are visited by aircraft to record the ground cover.

ground-truth site – may be either a training site used to train *ERMapper* prior to the supervised vegetation classification or an accuracy site used to assess the accuracy of the classification once it has been done.

image band selection – each LANDSAT TM image consists of 7 wavelength bands. Of these, only three are used when doing vegetation classification – generally, bands 5, 4, and 2. In the resultant multi-spectral image, each band is individually enhanced by computer software so that differences in ground cover are clearly apparent on the computer screen or printout.

image enhancement – amplification of spectral signatures so that even slight differences in ground cover are readily apparent.

image overview – hardcopy TM image printed at 1:500,000 scale, with selected ground-truthing sites clearly indicated and planned flight routes.

image section – hardcopy TM images printed at 1:100,000 scale are too large to be manageable; therefore, each was cut into 8 or more sections and laminated.

LANDSAT TM image – covers an area of approximately 180 x 180 km and is composed of 7 different wavelength bands with individual pixels that are 900 m^2. Each pixel has a single reflectance value that corresponds to one of our 39 ground cover classes.

site ID number – a unique identifying number and/or letter given each ground-truthing site.

site location – identifies the TM image on which a ground-truthing site is located. A site can be located on multiple images due to overlap.

spectral signature – each pixel on a LANDSAT TM image has a different spectral signature for each of the 7 wavelength bands. This is the amount of light reflected back to the satellite from the ground and differs according to the type of cover that occurs. By combining the spectral signatures from multiple bands (generally 3) for all the pixels in an image, we can classify vegetation.

supervised vegetation classification – ground-truthing sites where known vegetation data have been collected are entered into the computer so the classification software can group the remaining pixels into ground cover classes by their spectral signatures.

training site – those ground-truthing sites that are used to train computer software prior to a supervised vegetation classification.

training site overlap – a training site that occurs on ≥ 2 images due to overlap of adjacent images.

unclassified vegetation colour- original colour of the site (from 3 bands) prior to classification.

unsupervised vegetation classification – for each image, computer software can be used to identify any specified number of groups that have uniform spectral signatures. Those groups represent different ground cover classes. This type of classification can be done without extensive prior knowledge of the area or ground-truthing to train the software; however, groupings based on spectral signatures do not necessarily correspond to different cover classes.